ROPER'S

QUESTIONS FOR

ENGINEERS

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Questions and Answers

FOR

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BY

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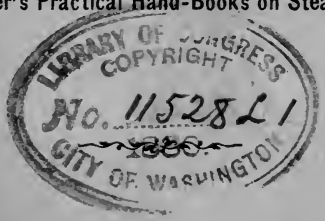

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INTRODUCTION.

THE following Questions embrace all that any engineer would be likely to be asked when undergoing an examination, but, of course, not one-quarter of them will ever be asked at any one examination; nevertheless, as the examiners have the right to vary the questions, it may be advisable for the candidate to make himself conversant with them all. Moreover, supervisors, when examining men for licenses as engineers in the mercantile marine, ask the same questions that the board of examiners for the United States revenue service do, and *vice versâ*, while engineers applying for certificates to take charge of stationary steam-engines are, in many instances, asked similar questions. In regard to this latter class, the inquiry is generally directed to ascertain their knowledge of steam-boilers and skill in their care and management.

But the questions and answers contained in this little book were not intended to meet all the requirements of a thorough preparation, but rather to suggest to candidates the nature of the questions that will be asked in a majority of cases, and the sources from which they might obtain ample information on each subject. No one is to blame for not being well informed on subjects on which he did not know where to obtain information; but, when once informed where it can be procured, if he fails to avail himself of the opportunity of so doing, he deserves no sympathy in his embarrassing position. Full information on every subject alluded to in the Questions and Answers may be found in Roper's Hand-Books for engineers.

There is too much laxity among engineers in general in regard to procuring valuable and important information on subjects relating to their calling. Legislation, that would require every one about to engage in this important calling to demonstrate that he understood the rudiments of the business, would have a salutary effect, and give guarantees of safety in many instances where not one shadow of them exists at present.

S. R.

ROPER'S
Questions for Stationary Engineers.*

Q. WHAT would you do first on entering the boiler-room in the morning?

A. I would ascertain if the water was at the proper height.

Q. Providing you thought the water was rather low, what course would you pursue?

A. I would start the injector or pump, providing I had sufficient steam to do so; if not, I would allow the water to run in from the street main or from the tank, as the case might be.

Q. How often ought a boiler to be cleaned?

A. As often as is practicable or convenient; at least once in every six months: the oftener, the better.

Q. How should boilers be treated preparatory to being cleaned?

A. They should be blown out and filled again, and the water allowed to remain in them until the cleaning is about to be commenced.

Q. What would be the object in allowing the water to remain in them up to the time of cleaning?

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*See Roper's "Catechism of Steam-Engines."

A. For the purpose of keeping the mud soft, and thereby preventing it from becoming firmly attached to the shell, tubes, etc.

Q. What would you do before blowing out a boiler?

A. I would remove all the fire from the furnace.

Q. What pressure should boilers be blown out under?

A. 35 to 40 pounds per square inch.

Q. What would be the objection to blowing out the boiler under 100 pounds pressure per square inch?

A. The change of temperature would be so sudden that it would cause the boiler to contract rapidly, and induce leakage or fracture.

Q. What effect has scale or deposit on steam-boilers?

A. It prevents the water from coming in contact with the plates, the result of which is the iron becomes burned.

Q. What is the effect of hard firing on steam-boilers?

A. In consequence of the heat being so intense the water is expelled from the plates, the result of which is that the fibre of the iron is destroyed and it becomes granulated, and in many instances as brittle as glass.

Q. Should dissolvents, which are placed in boilers to prevent and remove scale, be relied upon as effectual remedies for the evils resulting from incrustation?

A. No; as they frequently loosen and throw down large masses of scale, which, unless removed by blowing out, washing, or scraping, will cause the boiler to be burned through at that point.*

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* See Roper's "Use and Abuse of the Steam-Boiler."

Q. What precaution would you take before starting a fresh fire, or opening the draught, after the boiler had been standing some time?

A. I would ascertain if the water in the boiler was at the proper level.

Q. When starting a fresh fire under a boiler filled with cold water, how would you allow it to burn?

A. If I had sufficient time to get up steam I would allow it to burn gradually, as to let it burn fast would be objectionable.

Q. What would be the objection to allowing the fire to burn rapidly under a boiler filled with cold water?

A. Because it would produce unequal expansion and induce unnatural strains, in consequence of one side of the boiler becoming hot while the other was cold.

Q. What course would you pursue, if you discovered that the water was dangerously low in the boiler or boilers of which you have charge?

A. I would not allow the water to become dangerously low in any boiler that I had charge of; but, if it became low from circumstances over which I had no control, such as the pipe bursting or becoming stopped up, the well being pumped dry, or the supply being cut off, I would draw my fire.

Q. Don't you think the most careful engineer or fireman would be liable to forget his water sometimes?*

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* Do not ever admit that there would be any possibility of you forgetting anything connected with the care and management of steam-boilers, as such an admission would prevent you from getting a license.

A. No. I cannot see any reason why he should forget.

Q. Don't you know that the oldest, most cautious and careful engineers are prone to forgetfulness?*

A. That has not been my experience, consequently I am positive I would not forget the water supply, or anything else connected with the care and management of steam-boilers.

Q. Providing the water supply was cut off temporarily, what course would you pursue?

A. I would shut down the engine, cover my fire with fresh coal, shut the damper, open the furnace-doors, and retain the necessary quantity of water in the boiler until the supply would be restored.

Q. Providing you had to shut down your engine for a short time, with a high pressure of steam on the boiler, what course would you pursue?

A. I would cover my fire with fresh coal, close the damper and open the furnace-door, and start the pump or injector, at short intervals, while waiting.

Q. What would be the object in starting the pump or injector at short intervals?

A. To keep up the circulation of the water in the boiler, and prevent the plates directly in contact over and around the fire from becoming overheated and burned.

Q. Would you disturb the safety-valve under such circumstance?

A. No; as it might be attended with a certain amount of danger.

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* See Roper's "Engineer's Handy-Book."

Q. What proportion should the area of the safety-valve bear to the grate-surface?

A. About one-half square inch of safety-valve area to one square foot of grate-surface.*

Q. Would a boiler carrying 100 pounds steam pressure per square inch require a larger safety-valve than if the pressure was only 50 pounds per square inch?

A. No; it might be smaller, as the higher the pressure the higher the velocity; consequently, a given volume of steam, at 100 pounds pressure per square inch, would escape through a smaller orifice and in less time than the same volume would if the pressure was only 50 pounds per square inch.

Q. How often should the safety-valve be moved?

A. Every morning.

Q. What would be the object in moving it every morning?

A. To see that it was in good working order.

Q. How should safety-valves be treated?

A. They should be cleaned, repaired, and ground down to their seats as often as practicable.

Q. How could you tell whether the safety-valve was correctly marked or not?

A. I would observe the pressure on the steam-gauge when the steam was blowing off at the safety-valve, and if they nearly coincided I would consider them correct; but, if there was much variation between them, it would be evident that one or the other of them was incorrectly marked or out of order.

Q. How often should steam-gauges be tested?

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*See Roper's "Use and Abuse of the Steam-Boiler."

A. At least once a year, or whenever their recordance was supposed to be erroneous.

Q. What would you consider the duty of an engineer on taking charge of an engine or boilers for the first time in a strange place?

A. He should first see that the quantity of water in the boiler was ample, that the safety-valve was not overloaded, and that the steam-gauge was apparently in good order. He should next trace out all the pipes and connections between the water supply and the pump or injector, also between pump, the heater, and the boiler, and if the stop-cocks or valves were open or closed, according to their requirement of the objects for which they were intended.

Q. How often should boilers be tested and examined?*

A. As often as practicable; once in every six months, at least.

Q. Which is the most practical way of testing steam-boilers?

A. Either by sounding them all over their surfaces inside and outside, their stays, braces, and all the adjuncts and attachments, with a small steel hammer, for the purpose of determining if the boiler contains any cracks and flaws; or by applying hydraulic tests.

Q. How should the hydraulic test be applied?

A. The boiler should be blown out and filled again immediately, so that the heat remaining in the boiler may be transmitted to the water, for the purpose of warming it, as the temperature of the water in the

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* See Roper's "Use and Abuse of the Steam-Boiler."

boiler should never be less than 160° Fahr. when the test is applied.

Q. Would a boiler be stronger when subjected to any given steam pressure than if subjected to the same cold water pressure?

A. Yes, as the iron toughens with the heat up to 500° Fahr. A boiler will be less liable to burst under 80 pounds per square inch in pressure than the same boiler would be when subjected to 70 pounds per square inch cold water pressure.

Q. Are steam-boilers frequently injured by the hydraulic test?

A. Yes; many boilers are strained and fractured by an injudicious application of it.

Q. What is the meaning of the terms "longitudinal and curvilinear seams"?

A. The term "longitudinal" means the seams running along the side of the boiler, while the "curvilinear" are those running around the circumference.

Q. Why are the longitudinal seams generally double-riveted, while the curvilinear are only single-riveted?

A. Because there is twice the strain on the longitudinal that there is on the curvilinear seams.

Q. What is the meaning of the term "tensile strength"?

A. The term "tensile strength" means the resistance that boiler-plates would offer on being pulled apart on a straight pull in the direction of the grain or fibre of the iron.

Q. Is it advisable to leave some cock or valve open on steam-boilers while they are being filled with cold water?

A. Yes, as it allows the air to escape, and facilitates the filling of the boiler.

Q. Is it advisable to lift the safety-valve after a fresh fire has been started under it, when the boiler is filled with cold water?

A. Yes, as it allows the air which passed in with the water to escape, and which would otherwise prevent uniform expansion of the boiler.

Q. What are the objects of braces in steam-boilers?

A. They are a subterfuge for strength or to remedy weaknesses arising from wear or design.

Q. Give the names of the different braces employed in strengthening steam-boilers.

A. The vertical and horizontal, angle, toggle, dome, and crown braces; as well as the buckles, crow-feet, angle-irons, girths, stay-bolts, and leg braces. The tubes answer for braces for the tube-sheets; the crow-feet for the crown and dome.*

Q. Give the rule for finding the safe working-pressure of any boiler.

A. Multiply the thickness of iron by 56, if single-riveted, and 70, if double-riveted; multiply this product by 10,000 (safe load); then divide this last product by the external radius (less thickness of iron); the product will be the safe working-pressure in pounds per square inch, which, if multiplied by 5, would give the bursting pressure.†

Q. Why do you multiply the thickness of the iron by 56?

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* See Roper's "Engineer's Handy-Book."

† See Roper's "Use and Abuse of the Steam-Boiler."

A. Because the iron loses 44 per cent. of its strength in the process of punching. Double-riveted seams equal 70 of the original strength.

Q. What do you mean by the external radius?

A. The radius of any cylindrical vessel is half its diameter, and by taking half the diameter of a steam-boiler, and subtracting the thickness of iron from it, we get the internal radius.

Q. What do you mean by 10,000 safe load?

A. The tensile strength of boiler iron is generally capable of resisting a strain of 50,000 pounds per square inch, and one-fifth of that, or 10,000, is taken as safe load.

Q. What is the meaning of the term "heating-surface"?

A. It means all that portion of the steam-boiler exposed to the action of the fire and the heated gases in their escape from the furnace to the chimney.

Q. How many square feet of heating-surface is allowed per horse-power?

A. About 16 square feet.

Q. What is the average allowance of grate-surface to the horse-power?

A. About three-fourths of a square foot.

Q. Give the rule for finding the weight necessary to put on a safety-valve lever, when the area of valve, pressure, etc., are known?

A. Multiply the area of valve by the pressure in pounds per square inch; multiply this product by the distance of the valve from the fulcrum; multiply the weight of the lever by one-half its length (or its centre of gravity); then multiply the weight of valve and stem

by their distance from the fulcrum; add these last two products together; subtract their sum from the first product, and divide the remainder by the length of the lever; the quotient will be the weight required.*

Q. Give the rule for finding the pressure per square inch on a safety-valve when the area of valve, weight of ball, etc., are known.

A. Multiply the weight of ball by the length of lever, and multiply the weight of lever by one-half its length (or its centre of gravity); then multiply the weight of valve and stem by the distance from fulcrum. Add these three products together. This sum divided by the product of the area of the valve, and its distance from the fulcrum, will give the pressure in pounds per square inch.

Q. If the boiler was too small for the engine, and you found it difficult to keep up the speed, would you place extra weights on the safety-valve lever for the purpose of carrying extra pressure?

A. No; because such an act on the part of an engineer would be a piece of culpable recklessness.

Q. If the water supply should fail from any cause, and your employer was anxious to finish up some work he had in hand, would you continue running until the water became dangerously low?

A. No. I would not run any risk on any consideration whatever, under the influence of my employer or any one else.

Q. What kind of steam-boilers are you acquainted with?

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* See Roper's "Use and Abuse of the Steam-Boiler."

A. Nearly all kinds in use.

Q. To what strains are different parts of steam-boilers subjected?

A. The shells are subjected to a tearing strain and the flues or tubes * to a crushing strain.

Q. Would a steam-boiler resist as much pressure if exerted on the outside of the shell as if the same pressure was exerted on the inside?

A. No; as pressure exerted on the inside of a boiler has a tendency to preserve its cylindrical form, while that exerted on the outside has a tendency to destroy it.

Q. What is the meaning of the term collapse, when applied to the flues of steam-boilers?

A. The term collapse means to crush in or flatten.

Q. Will a flue of a certain diameter and thickness of iron, 20 feet long, stand as much pressure before collapsing as a flue of the same diameter and same thickness of iron 10 feet long would?

A. No; a short flue would stand twice as much pressure before collapsing as a long one.

Q. What is the principal cause of boiler explosions?

A. Weakness in the shell or other parts of the boiler.

Q. To what causes may such weakness be attributed?

A. Poor material, inferior workmanship, bad design, neglect, overpressure, excess of firing, etc.

Q. Is there any mystery about boiler explosions?

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* See Roper's "Use and Abuse of the Steam-Boiler."

A. No; when such an event does occur, it is evident that the boiler did not possess sufficient strength to resist the pressure, or that the pressure was too great for the boiler.

Q. Give the type and dimensions of the boiler you had charge of last.

A. It was a return tubular; diameter 48 inches, 14 feet long, wrought-iron heads, thickness of iron in shell $\frac{5}{16}$, 46 3-inch tubes, 15 square feet of grate surface, safety-valve 3 inches in diameter, working pressure 65 pounds per square inch.*

Q. What kind of an engine had you charge of last?

A. Horizontal slide-valve; diameter of cylinder 12 inches, stroke 24 inches, number of strokes 150 per minute, steam pressure 55 pounds per square inch, steam cut-off at half stroke by means of a positive cut-off (or lap on the valve).

Q. What kind of a steam-gauge did you have?

A. A spring gauge.

Q. Did you use a pump or injector?

A. Both were used.

Q. What sized pump or injector would you consider sufficient for any steam-boiler?

A. One that would throw a cubic foot of water every hour for every horse-power for which the boiler was rated.

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* Every engineer should know the exact size of the boiler in his charge; the diameter, length, thickness of iron, number and diameter of tubes or flues, area of safety-valve, square feet of grate surface; he should also know the proportion of the engine, and whether slide- or poppet-valve, automatic, cut-off, or throttling.

Q. What are the causes which are most likely to keep pumps from working ?*

A. Insufficiency of water, the suction-pipe becoming choked with mud, leakage in the pipes, the valves being prevented from taking their seats by straw, shavings, or other substances being carried in with the water, or the pump-valves becoming hot, thereby causing the valves to expand and stick.

QUESTIONS FOR MARINE ENGINEERS.

Q. How long have you served as a fireman ?

A. ... years.

Q. How long have you served in the engine-room at sea, and in what capacity ?

A. ... years.

Q. With what description of engines have you served at sea,—paddle or screw, jet-condensing, surface-condensing, or non-condensing engines, compound, trunk, inverted, or oscillating ; and what size were they ?

A. The engines of the steamboat were ..... x ....., and the engines on the steamship on which I was engineer were ..... x ....., surface condensing, ... compound or simple, or jet-condensing, as the case may be.

Q. Explain the difference between condensing and non-condensing engines.

A. In the case of the condensing engine, the steam is exhausted into a condenser ; while in the case of

* See Roper's "Hand-Book of Modern Steam Fire-Engines."

the non-condensing, it is exhausted into the atmosphere.

Q. What is the difference in effect between condensing and non-condensing engines?

A. A condensing engine will develop as much power, with 35 pounds pressure per square inch, as a non-condensing of the same size would with 50 pounds per square inch.

Q. Explain the difference between jet- and surface-condensers.

A. In the surface-condenser the steam is condensed by being brought in contact with a cold surface, while in the jet-condenser the steam is condensed by the introduction of cold water into the condenser.

Q. Explain the advantages of jet- or surface-condensers.

A. As in the case of the surface-condenser, the injection water is not mixed with the water of condensation; the boilers are at all times supplied with fresh water; thus preventing the formation of scale, making a saving in the consumption of fuel, and increasing the durability of the boiler; while in the case of the jet-condenser, the injection water mixes with the water of condensation, and, as a portion of it has to be taken to supply the boiler, which has the effect of forming scale, induces wastefulness of fuel, ending eventually in the destruction of the boiler.*

Q. Has the air-pump the same amount of duty to perform in the case of surface- and jet-condensers?

A. No. In the surface-condenser the air-pump has

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*See Roper's "Engineer's Handy-Book."

only to extract the air and the water of condensation; while in the case of the jet-condenser, it has to extract the air, the water of condensation, and the injection water.

Q. What do you mean by the terms injection water and water of condensation?

A. The injection water is the water introduced into the condenser for the purpose of condensing the steam; while the water of condensation is water which results from the condensation of the steam.

Q. What is the meaning of the term "vacuum"?

A. A void, or empty space, where there is neither water, steam, nor air.

Q. How is a vacuum created in the condenser before the engine is started?

A. By opening the snifting-valve and allowing the steam to go through and expel the air; then by closing the snifting-valve and introducing the injection water, when the vacuum is produced.

Q. How is the vacuum maintained in the condenser?

A. By the injection water and the air-pump.*

Q. Can a perfect vacuum be maintained?

A. No.

Q. How much steam will a cubic inch of water produce at the pressure of the atmosphere, or 15 pounds to the square inch?

A. 1728 inches, or one cubic foot.

Q. How much injection water does it require to condense steam?

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* See Roper's "Engineer's Handy-Book."

A. About twenty-one times the quantity from which the steam was generated.*

Q. What proportion does the cooling surface of the condenser bear to the horse-power of the engines with which they are connected?

A. About $6\frac{1}{2}$ square feet to the indicated horse-power.

Q. What proportion does the air of the circulating pump bear to the cooling surface in surface-condensers?

A. About one cubic foot of capacity of circulating pump to 500 feet of cooling surface in the condenser.

Q. Of what material are the tubes of surface-condensers usually made?

A. Either of brass or copper.

Q. What proportion should jet-condensers bear to the capacity of the cylinder?

A. They should be from $\frac{1}{15}$ to $\frac{1}{20}$ of the capacity of the steam-cylinder.

Q. What is the most economical temperature at which to keep the water in the hot-well?

A. From 100° to 110° Fahr.

Q. What would be the effect of a higher or lower temperature?

A. A higher temperature would affect the vacuum, while a lower temperature would induce a loss of heat, and consequently would be a waste of fuel.

Q. What causes would be most likely to impair the vacuum?†

A. An insufficient supply of injection water, leak-

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* See Roper's "Engineer's Handy-Book."

† See Roper's "Engineer's Handy-Book."

age of the condenser in the air-pump or in any of the connections.

Q. How is the exact amount of vacuum determined?

A. By the vacuum-gauge.

Q. What is the meaning of 16 inches of mercury, etc.?

A. As two inches of mercury represent one pound pressure; 16 inches represent an 8-pound vacuum; 18 inches a 9-pound; 20 inches a 10-pound, and so on.

Q. Explain the difference between simple and compound engines.

A. In simple engines the steam is used once; after which it is exhausted into the atmosphere or condenser; while in the compound engines the volume of steam is used twice: as it is admitted from the small cylinder to a large one, and then escapes through the condenser.

Q. What is the meaning of the term marine engine?

A. It has no definite meaning.*

Q. What parts of marine engines are most likely to disable a ship in case of breakage?

A. If the piston-rod, crank-pin, crank, connecting-rod, cross-head, or valve-rod should break, it would disable the ship, if there were none on board to replace them.

Q. Providing a crank-pin, main-bearing, or truss-block should heat excessively, what course would you pursue?

A. I would oil them frequently; and if that did not

* See Roper's "Engineer's Handy-Book."

prevent the heating, I would turn a stream of cold water on them from a hose.

Q. Providing your pump failed to work, your water was low, and you were likely to be driven ashore, what course would you pursue?

A. I would head the vessel to the sea, and proceed in that direction until I could remedy the difficulty.

Q. What causes would be most likely to prevent a pump from working?

A. See answer on page 17.

Q. If the follower-plate should break at sea, what course would you pursue?

A. I would attempt to repair it with boiler-plate and tap-bolts, provided these materials were on board; if not, I would detach the propeller-shaft and proceed under sail to the nearest port.

Q. Providing the air-pump-rod should break, and there was no extra rod on board, how would you act?

A. I would remove the air-pump bucket and foot-valve, and rig a temporary exhaust-pipe with lumber, and work the engine non-condensing.

Q. If the cylinder-head should be fractured or split, what course would you pursue?

A. I would attempt to repair it with pieces of iron, plank, and canvas, or whatever other material I could find on board. If I failed, I would draw my fires and proceed under sail.

Q. If the cut-off should break at one end?

A. I would remove it from the other end and work steam whole-stroke.

Q. If the crank-pin should break, what course should you pursue?

A. I would remove the broken pin by heating it with fire, and replace it with a new one, providing there was one on board. If not, I would detach the propeller-shaft and proceed under sail.

Q. If the propeller-shaft should twist off, what course would you pursue?

A. I would disconnect it from the engines, and proceed under sail.

Q. Give the names of the different pipes, cocks, and valves used in connection with marine engines.

A. See Roper's "Engineer's Handy-Book," page 231.

Q. What are the functions of the air-pump used in connection with the steam-engine?

A. To extract the air, the injection-water, and the water of condensation.

Q. What relative proportion should the air-pump bear to the steam-cylinder?

A. The capacity of the air-pump should be about $\frac{1}{15}$ of the capacity of the steam-cylinder.

Q. What is the object of the marine steam-engine register or counter?

A. To tell the number of revolutions that the engine made on the passage.

Q. Give the rule for finding the number of revolutions the engine has made during the voyage.

A. Subtract the number at which the counter stood at the beginning of the voyage from that which is indicated at the end of it; the remainder will be the number of revolutions made during the voyage.*

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*See Roper's "Engineer's Handy-Book."

Q. What is the object of the salinometer?

A. To tell the quantity of saline matter in the water in the boilers of marine engines.

Q. What are the functions of the barometer?

A. The barometer is an instrument used for observing the pressure and elasticity, or variations in density, of the atmosphere.*

Q. Explain the different marine light, whistle, and bell signals for river and lake boats and ocean steamers.

A. See Roper's "Engineer's Handy-Book," pages 389–391.

Q. Explain the meaning of the term "pitch of the screw," when employed in relation to screw-propellers used for the propulsion of vessels.

A. The "pitch of the screw" is the distance that it would advance in one revolution, if working in a solid, fixed nut; or it is the distance between the threads measured in a line with the shaft.

Q. Explain the meaning of the term "slip of the screw."

A. The term "slip of the screw" means the difference between the actual advance of the propeller through the water, and the advance which would be accomplished, if there was no recession of the water produced by the pressure of the propelling surface.†

Q. Upon what condition do the advantages of the paddle-wheel depend?

A. On the amount of its immersion in the water.

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*See Roper's "Engineer's Handy-Book."

†See Roper's "Hand-Book of Land and Marine Engines."

Q. What is the meaning of the term "slip of the paddle"?

A. The difference between the speed of the ship and that of the wheel.

Q. Give the rule for finding the safe working-pressure of a boiler, the diameter and the thickness of iron being known.

A. See page 12.

Q. Give the names of the different adjuncts of steam-boilers.

A. See Roper's "Engineer's Handy-Book," pages 476–478.

Q. How high will an ordinary pump lift water?

A. 33 feet.

Q. What is the object of placing an air-vessel on a pump?

A. To induce a better supply of water, and prevent concussion or jar whenever the piston strikes the water.*

Q. Give rule for finding diameter of pump-plunger for any engine.

A. The diameter of the steam-cylinder multiplied by 0·3 will give the proper diameter of pump-plunger.†

Q. Give the names of the different minerals that constitute the basis of scale in steam-boilers.

A. The minerals which constitute the basis of the scale which forms in steam-boilers using fresh water from wells, lakes, or rivers, are, sulphate of lime, phosphate of lime, carbonate of lime, magnesia, silica,

*See Roper's "Hand-Book of Modern Steam Fire-Engines."

†See Roper's "Engineer's Handy-Book."

and alumina, with small quantities of sesquioxide of iron, baryta, carbonic acid, organic matter, chlorine, sulphuric acid, potassa, calcium, soda, phosphoric acid, magnesium, etc. The remedies for the prevention and removal of scale are almost innumerable.

Q. Explain the cause of foaming in steam-boilers.

A. Foaming in marine boilers using jet-condensers is generally caused by changing the water from salt to fresh, and *vice versâ;* the boiler being foul, insufficient steam-room, etc.

Q. Give the meaning of the term "priming."

A. The term priming is understood by engineers to mean the passage of water from the boiler to the steam-cylinder in the shape of spray.

Q. Give the meaning of the term "corrosion," and explain its analogy to combustion.

A. The term corrosion means wasting, pitting, or grooving of the material, and is generally referred to under two heads, namely, internal and external. External corrosion is said to be due to the galvanic action of the mineral in the fuel and the gases in the atmosphere, and both are intimately associated with combustion, or stimulated by it. The acids and minerals which are in solution in the water, and liberated by the heat, attack the boiler internally; and the sulphur which is liberated by the combustion of coal has a strong affinity for the iron, and attacks it externally.

Q. Give the rule for finding the horse-power of steam-engines.

A. Multiply the area of the piston by the average pressure in pounds per square inch; multiply this pro-

duct by the number of feet the piston travels in a minute, and divide by 33,000. The quotient will be the horse-power.

Q. Give the rule for finding the horse-power of steam-engines from indicator diagrams.

A. Multiply the area of the piston by its travel in feet per minute, and divide by 33,000; the quotient multiplied by the mean effective pressure shown by the diagram will be the horse-power.*

Q. Give the names of the different designs of steam-engines in use.

A. Horizontal, vertical, inclined, oscillating, trunk, geared, steeple, etc.*

Q. Give the names of the different classes into which engines are subdivided.

A. Single-acting, double-acting, direct-acting, back-action, etc.†

Q. Give the different terms employed in expressing the horse-power of steam-engines.

A. Nominal, indicated, actual, nett, dynamometrical, commercial horse-power, etc.

Q. What is the nominal horse-power of a steam-engine?

A. 33,000 pounds raised one foot high in one minute; 150 pounds raised 220 feet high in the same time, or 550 pounds raised one foot high in one second.

Q. How may these different units of weight be raised?

A. By belts, pulleys, cog-gearing, cables, paddle-wheels, propellers, or such other mechanical applications as are most practicable and convenient.

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* See Roper's "Engineer's Handy-Book."

† See Roper's "Hand-Book of Land and Marine Engines."

NECESSARY QUALIFICATIONS

FOR

FIRST ASSISTANT ENGINEERS IN THE U. S. REVENUE-CUTTER SERVICE.

First. They must pass before the board of examiners a thorough examination upon the subjects prescribed for second assistant engineers, and be able to explain the principles, peculiarities, functions, and uses of the different kinds of valves and valve-gear, as applied to marine steam machinery.

Second. They must understand the construction, principles, peculiarities, and uses of the various mechanical arrangements employed in working steam expansively.

Third. They must understand the construction of the marine boilers in most general use, their attachments, and the functions and uses of the same.

Fourth. They must be able to explain the most general causes of derangement in the operation of air- and feed-pumps and pipes, and the most practicable method of preventing and remedying them.

Fifth. They must have a knowledge of the chemical and mechanical causes which induce the formation of scale in steam-boilers, and the most practicable method of preventing and removing the same.

Sixth. They must be acquainted with the general construction, principles, peculiarities, and uses of the different kinds of surface-condensers in present use.

Seventh. They must be able to calculate the loss induced by blowing off, for the purpose of keeping the

water in the boilers at a uniform degree of saturation, and understand the principles of the various instruments employed to determine the water's saturation, as well as the method of graduating them.

Eighth. They must understand the principles, most practicable limits, and advantages of working steam expansively, and be able to calculate the same.

Ninth. They must have a knowledge of the construction of the indicator, know how to apply it, and intelligently explain its diagrams.

Tenth. They must be acquainted with the construction and the principles on which the action of steam- and vacuum-gauges is based, and the causes of their derangement.

Eleventh. They must have experience in building, erecting, and repairing steam machinery.

Twelfth. Candidates for appointment as second assistant engineers must not be less than twenty-one nor more than thirty years of age; they must be of good moral character and correct habits; they must have worked not less than eighteen months in a steam-engine factory, or served the same period as an engineer on board of a steamer having a condensing engine; they must also produce favorable testimonials from the superintendent of the machine-shop, or chief-engineer of the steamship, as to their ability.

Thirteenth. They must be able to describe and sketch the different parts of marine steam-engines and boilers, and explain their uses and mechanical movements, the method of putting them in operation, regulating their action, and guarding against danger.

Fourteenth. They must be fair arithmeticians and

have a knowledge of rudimentary mechanics, be capable of writing a fair, legible hand, and have some knowledge of chemistry, particularly of combustion and corrosion.

Fifteenth. Candidates who excel in practical experience and professional skill will be given the preference, both in admission and promotion.

Sixteenth. Any candidate producing a false certificate of age, time of service, or character, or making a false statement to the board of examiners, will be dropped from the list.

Q. Give the rule for finding the quantity of coal required to drive a steamship a given number of days in average fair weather.

A. The beam in feet squared will give the quantity of coal required in nett tons.

Q. Give the rule for finding the percentage of loss induced by blowing off to prevent saturation.

A. Multiply loss by blowing off by 100, and divide the product by the total degrees of heat imparted to the water, plus the heat lost by blowing off. (Observe that for $\frac{3}{3\frac{2}{2}}$ as twice as much water is converted into steam as is blown off. For $\frac{2}{3\frac{2}{2}}$, the amount is equal. For $\frac{1\frac{3}{4}}{3\frac{2}{2}}$, the amount is $\frac{3}{4}$, and so on.) The result is the percentage of loss.*

Q. Give the rule for finding the amount of gain derived from working steam expansively.

A. Divide the length of the stroke in feet by the cut-off, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{2}$, as the case may be; then find, on the table on page 68 in Roper's "Engineer's Handy-

*See Roper's "Engineer's Handy-Book."

Book," the hyperbolic logarithm nearest to that of the quotient, to which add 1. This sum will give the ratio of gain.

Q. Give the rule for finding the mean or average pressure in the cylinder of a steam-engine.

A. Divide the length of the stroke in inches (including the clearance) by the distance that the steam follows the piston before being cut off; the quotient will be the expansion the steam undergoes. Then find in the expansion column, in the following table, the number corresponding to it; take the multiplier opposite, and multiply the full pressure of the steam per square inch, as it enters the cylinder, by it. The product will be the average pressure.*

Q. Give the rule for finding the point of cut-off required to produce a given terminal from a given initial pressure.

A. Divide the total terminal by the total initial pressure. The quotient will be the point of cut-off in decimal parts of the stroke.

Q. Give the rule for finding the point of cut-off when the initial and mean pressures are known.

A. Add the pressure of the atmosphere to the initial and mean pressures, and divide the mean pressure by the initial. Then find in the table of multipliers, page 69 of Roper's "Engineer's Handy-Book," the number nearest to the quotient. Find the number opposite to it in the expansion column, and divide 100 by it; the quotient will be the point of cut-off in decimal parts of the stroke.

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*See Roper's "Engineer's Handy-Book," page 68.

Q. What is the object and use of indicator diagrams?*

Q. What can be ascertained from them?*

Q. How do they show the power exerted by an engine?*

Q. How does the diagram show the steam-pressure?*

Q. How does it show the back pressure?*

Q. How does it show the setting of the valves?*

Q. How does it show a leaky piston?*

Q. Sketch diagram, and explain it.*

Q. How does the expansion curve show that the steam is throttled?*

Q. Show the point of cut-off on the diagram.*

Q. Show the effect of leaky piston and leaky valves.*

Q. Show the effect of small ports.*

Q. Show the effect of lead upon steam and exhaust valves.*

Q. Give the rule for calculating the mean and terminal pressure from indicator diagrams.*

Q. Give the meaning of the terms "atmospheric line," "admission line," "steam line," "expansion line," "exhaust line," "compression line," "boiler-pressure line," "vacuum line," "clearance line," and "line of counter-pressure."*

Q. What is the meaning of the term "theoretic curve"?*

Q. What is force, motion, velocity, and momentum, gravity, percussion, inertia?*

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*See Roper's "Engineer's Handy-Book," Part IV.

Q. What is combustion?

A. The development of heat by chemical combinations.

Q. What are the products of combustion?

A. Steam, carbonic acid, carbonic oxide, smoke, etc.

Q. How is steam formed in boilers?

A. By ebullition, which is caused by the application of heat to the outside of the vessel containing the fluid.

Q. What is smoke?

A. The exhalation from burning substances.*

Q. What is coke?

A. The substance left in the retorts after the gas from the coal has been expelled.

Q. What is coal?

A. A black, combustible fossil of vegetable origin.

Q. What is carbonic acid?

A. An elastic fluid formed from that portion of constituent carbon which has not chemically combined in the proportion of 16 of oxygen to 6 of carbon by weight.

Q. Show the loss by blowing off at different degrees of saturation.*

Q. State the means most frequently resorted to to prevent foaming.*

Q. How is scale formed in steam-boilers? †

Q. Show the gain derived from using a heater. ‡

Q. How is scale removed from steam-boilers? †

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* See Roper's "Engineer's Handy-Book."

† See Roper's "Use and Abuse of the Steam-Boiler."

‡ See Roper's "Hand-Book of Land and Marine Engines."

Q. Explain the objects, functions, and mechanism of steam- and vacuum-gauges.*

Q. What are the advantages of spring over mercury steam-gauges, and *vice versâ*? †

Q. Is there any gain in generating steam of high-pressure over that of low-pressure?

A. Yes; because it is more expansive.

Q. Explain the different appliances for working steam expansively.

A. See Roper's "Engineer's Handy-Book" on the subject of cut-offs.

Q. What is the meaning of the term "lead on the valve"?

A. The amount of opening the valve has for the admission of steam when the piston is at the commencement of the stroke.

Q. What is the meaning of the term "lap on the valve"?

A. The amount the valve overlaps each steam-port when in the centre of its travel.

Q. What is foam?

A. A mixture of steam and water.

Q. Give the names of the different valves and valve-gear employed on all classes of steam-engines.‡

Q. Explain the difference in the mechanism of the Stevens, Winter, and Sickel cut-offs.

A. See Roper's "Engineer's Handy-Book" on the subject of cut-offs.

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* See Roper's "Engineer's Handy-Book."

† See Roper's "Hand-Book of Land and Marine Engines."

‡ See Roper's "Use and Abuse of the Steam-Boiler."

Q. What would be the difference in effect between a condensing and non-condensing engine of the same size and working with equal boiler pressure?

A. A condensing engine would do as much work as the non-condensing with 14 pounds per square inch less pressure.

Q. Give the approximate weights of different metals.*

Q. To what order of levers does the safety-valve lever belong?

A. To the third order.

Q. What elements are embraced in the mechanical powers?

A. The wheel and axle, inclined plane, wedge, pulley, and screw.*

Q. What is geometry?*

Q. What is an axiom?*

Q. What is a theorem?*

Q. What is a solution?*

Q. What is a corollary?*

Q. What is trigonometry?*

Q. What is corrosion?

A. Wasting away of material of which boilers are made, caused by chemical action of the acid in the water.

Q. What is the meaning of the term "travel of the valve"?

A. The distance the valve moves on its seat.

Q. What is the meaning of the term "throw of the eccentric"?

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* See Roper's "Engineer's Handy-Book."

A. See Roper's "Engineer's Handy-Book," subject "Eccentric."

Q. What is the meaning of the term "cam"?

A. It has no definite meaning.

Q. Does adding lap to the valve necessitate the altering of the position of the eccentric?

A. Yes.*

Q. What would be the probable effect of an accumulation of water in the cylinder?

A. It would be liable to cause a fracture of the cylinder-head, the piston, or spring the joints.

Q. How does the steam enter the cylinder?

A. Through the steam-ports.

Q. How does the steam escape from the cylinder?

A. In ordinary slide-valve steam-engines it escapes through the same openings by which it enters; but in other arrangements it escapes by an independent exhaust-valve.

Q. What are the advantages of the ordinary slide-valve?

A. Simplicity of design, moderate first cost, and positive action.

Q. What are its disadvantages?

A. Its wastefulness.*

Q. What are the advantages of poppet- or double-beat valves?

A. They are nearly balanced, and require very little power to work them.

Q. What are the disadvantages of poppet- or double-beat valves?

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* See Roper's "Catechism of High-Pressure or Non-Condensing Steam-Engines."

A. They are difficult to keep steam-tight, and at high-piston velocities they would not seat.

Q. What are the advantages of vertical over horizontal steam-boilers for marine purposes?

A. Economy of space.

Q. How much water can be evaporated by one pound of coal, in tubular boilers, under the best conditions?

A. About eight pounds.

Q. What is the meaning of the term "calorimeter"?

A. Calorimeter means the area of the flue through which the hot gases escape from the furnace.

Q. What is the meaning of the term "vent"?

A. The calorimeter of the flue in inches divided by its length in feet is termed the vent.

Q. Give the height, weight, and component parts of air.*

Q. Into what two classes may pumps be divided?

A. Lift or suction and force; and these, again, into single-acting, double-acting, rotary, centrifugal, bucket-plunger, and solid piston.

Q. Which of the foregoing pumps do you consider the best?

A. Each of them was designed for some special object, and probably meets the requirements of that better than any other.

Q. What are the meanings of the terms "acceleration," "affinity," "angle," "axle," "capillary attraction," "friction," "gravity," "gyration,"

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* See Roper's "Engineer's Handy-Book."

"hydrodynamics," "hyperbola," "impact," "impenetrability," "impetus," "incidence," "inclination," "inclined plane," "inertia," "mass," "matter," "mechanical powers," "modulus," "momentum," "motion," "oscillation," "percussion," "pneumatics," "power," "prime movers," "statics," "tools," "tortion," "velocity," "weight," and "work"?

A. See Roper's "Engineer's Handy-Book," under the head of "Central and mechanical forces."

Q. Specify the different kinds of motions recognized in mechanics.

A. Absolute, accelerated, angular, compound, natural, parallel, relative, retarded, uniform, and rotary.*

Q. What is the cause of draught in chimneys?

A. Draught is caused by the difference in weight of a column of rarefied air passing over or through a fire and that of the atmosphere at an ordinary temperature.

Q. How much steam-room would you allow in a steam-boiler?

A. About one-fourth of the cubic contents.

Q. What are the meanings of the terms "water-space" and "steam-room" when applied to steam-boilers?

A. The term water-space means that part occupied by the water, while the term steam-room is the part occupied by the steam.

Q. What is the object in using a gib and key on the stub-ends of a connecting-rod?

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* See Roper's "Engineer's Handy-Book."

A. To take up the lost motion.

Q. Why are stub-end straps made thicker at the point where the key passes through than at any other?

A. To compensate for the amount of material taken out in the slot.

Q. What kind of condensers are you acquainted with?

A. With all kinds.

Q. What are the advantages of a surface-condenser over a jet-condenser?

A. They furnish fresh water to the boiler, thereby preventing scale, saving fuel, and also saving the boiler.

Q. How does the injection-water enter the condenser?

A. In the case of the jet-condenser, it rises through the ship's side and into the condenser, the quantity being regulated by a cock or valve; while in the surface-condenser it is lifted from the sea, lake, or river, by the circulating-pump, and forced through the tubes.

Q. How are the tubes of surface-condensers made tight?*

Q. What circumstances would be most likely to effect a vacuum?

A. Insufficiency of injection-water, leakage in the tubes, air-pump, or some of the connections.

Q. What is the most advantageous point to cut off steam when used expansively?

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* See Roper's "Engineer's Handy-Book."

A. About five-eighths of the stroke.

Q. How is scale prevented from forming in a boiler?

A. By using a surface-condenser and surface blow-off.

Q. At what distance should the air-pump be placed from the condenser?

A. The air-pump should be as near the condenser as possible.

Q. Should the air-pump be placed above or below the condenser?

A. It would be more advantageous to place it so that the openings of the air-pump would come on a line with the openings of the condenser.*

Q. Would a pump labor under any disadvantage when working salt water at one end and fresh water at the other end?

A. Yes; there would be more strain at the end at which it was working salt water, on account of its being more dense.

Q. Give the names of the different steam-boilers in most general use, their peculiarities of design, advantages, disadvantages, how fired, etc.

A. Plain cylinder, horizontal, vertical, tubular, return flue, drop flue, locomotive, double deck, fire and water, tubular, fire-box, etc.

Q. How are steam-boilers in general fired?

A. The plain cylinder, return flue, and most of the tubular are fired externally, while locomotive and marine fire-box boilers are fired internally. Some designs of tubular boilers are fired internally. For

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* See Roper's "Engineer's Handy-Book."

full information on this subject, see Roper's "Use and Abuse of the Steam-Boiler."

Q. How high must a conical- or poppet-valve lift to give an opening equal to its area?

A. One-half of its radius or one-fourth its diameter.*

Q. Is the Sickel cut-off positive or adjustable?

A. Adjustable.

Q. Is the Winter cut-off adjustable?

A. Yes.

Q. Is the Stevens cut-off adjustable?

A. Yes.

Q. From what part of the engine do the Stevens, Sickel, and Winter cut-offs receive their motion?

A. From the eccentric.

Q. What objection is there to a Sickel valve-gear when a ship is laboring?

A. It will not release the valves; and, as a result, the engine will jump and race.

Q. Do you know any independent means of working the valves of steam-engines?

A. Yes, by hand.

Q. Does the Stevens, Winter, and Sickel arrangement cut off at exactly the same point at each end of the stroke?

A. No. It would be impossible to equalize the cut-off when it receives its motion from an eccentric, on account of the angularity of the rod.†

Q. Is it customary to give more lead on the lower steam-ports than on the upper ones, and if so, why?

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* See Roper's "Hand-Book of Land and Marine Engines."

† See Roper's "Engineer's Handy-Book."

A. Yes; so as to compensate for the weight of the piston, cross-head, connecting-rod, and crank.

Q. How would you stop a steam-engine, provided the stop-valve was broken?

A. I would release or throw out the valve-gear, and move the valve entirely over both ports, by means of the starting-bar.

Q. Provided your eccentric slipped on the shaft, how would you proceed to adjust it?

A. I would place the crank on the dead-centre, remove the bonnet of the steam-chest, and turn the eccentric around in the direction it is intended to run, until the valve had the proper amount of lead on that end. I would then make the eccentric fast, and place the crank on the other centre; and if the lead was the same at both ends, I would adjust the eccentric permanently; if not, I would equalize the lead before so doing.

Q. Is pressure weight?

A. No. Pressure exerts its force in every direction, while weight presses only in one.*

Q. How do you determine the pressure of steam in a steam-boiler?

A. There are three ways of ascertaining the pressure in a boiler,—first by the gauge, second by the safety-valve, and third by the temperature.

Q. How would you proceed to ascertain the pressure, providing you had neither steam-gauge nor safety-valve?

A. I would take a bottle, or other vessel with a neck

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*See Roper's "Engineer's Handy-Book."

of sufficient width to admit a thermometer. I would then hold it under one of the gauge-cocks, or some other small pipe attached to the boiler, and allow the steam to flow in; then, by withdrawing the thermometer quickly, the temperature would show the pressure, as temperature and pressure are constant factors.

Q. Can you illustrate the above explanation by an example?

A. Yes. Suppose the pressure was 15 pounds per square inch, the thermometer would register 212° Fah.; if the pressure was 20 pounds, it would show 228.5°; if 40 pounds, 269.1°; if 60 pounds, 295.6°, and so on.

Any other questions, not contained in this book, will be answered by the author on the application by letter, or otherwise, of any one who has purchased a copy.

For all questions relating to cadetships in the United States Navy, see Roper's "Engineer's Handy-Book."

DEPARTMENT OF STEAM-BOILER INSPECTION.

Engineer's Certificate.*

THE UNDERSIGNED, Inspector in and for the City and County of ....., certifies that he has examined into the qualifications of JOHN SMITH, and finds him to be a suitable person to be intrusted with the power and duties of a .....Class Engineer, and do empower him to act as such for one year from this date, upon his complying with the rules of this Department.

Given under my hand and a seal of this Department, this.....
*day of.....*18

JOHN DOE,
Inspector.

* This Certificate will be revoked on proof of negligence, insobriety, and non-compliance with the rules issued by this Department.

The above form represents the license generally issued to the Engineers having charge of Stationary Steam-Engines and Boilers.

Application for License as Marine Engineer.*

Date.....*1880.*

TO THE U. S. INSPECTOR OF STEAMBOATS.

I hereby respectfully apply for license as....., *and submit the following statement of my experience and testimonials of character and qualifications:*

I served three years as fireman on the Steamboat.....,
Captain....., *plying between*..... *and*.....
I served two years as an engineer on the Steamship.....,
Captain....., *running between*..... *and*.....
And I further say that I have not made application to the inspector of any other district and been rejected.

Sworn to before me *this*.....*day of*.....1880.

.....*Inspector.*

We, the undersigned, do certify, from our knowledge of the above named.....,
that he is a person of temperate habits and of good character, and recommend him as a suitable person to be entrusted with the duties of the station, as above, for which he makes application.

.....

.....

.....

* Blanks for the above Forms can be procured at any U. S. Supervisor of Steamboats' Office.

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